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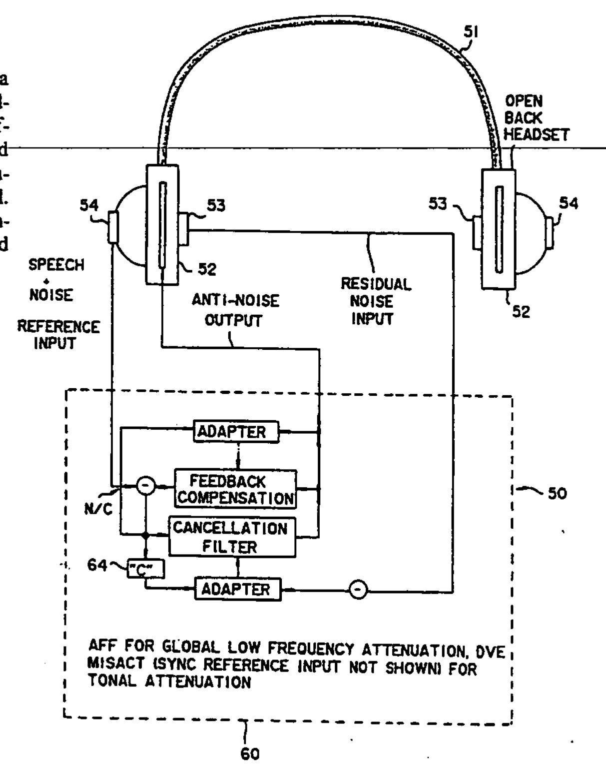
(54) Title: ACTIVE SELECTIVE HEADSET

(57) Abstract

An active selective headset system characterized by a headset (51) having controller means (50) with an LMS adapter, feedback compensator and cancellation filter with reference microphone (54) and residual microphones (53) and speakers (52), where the controller means synthesizes an "anti-noise" to cancel the noise before reaching the ear canal. The headset which is selective, i.e., "anti-noise" signal cancels only the noise signal with minimal affect on speech and warning signal which pass to the ear canal.



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ACTIVE SELECTIVE HEADSET

This invention relates to a headset to provide active, as opposed to passive, protection for a wearer/user.

In industrial environments there is often a demand for active headsets that attenuate low frequency noise as well as noise covering the speech band (300 to 3300 Hz). While passive hearing protection works well at higher frequencies above 1000 Hz, active technology achieves similar levels of protection at the lower frequencies of 50 to 1000 Hz. The added problem of passive is that it also attenuates speech.

The instant invention provides a solution that provides the protection offered by a passive headset in a light weight open-back design using any of several active control algorithms that selectively cancel only the damaging noise with minimal effects on speech and warning signals.

In the past, attempts to combine the two protections i.e., high and low frequency attenuation, has resulted in not only the noise being attenuated but also the speech that the wearer needs to hear. Some systems met only limited success with fixed or "near-stationary" noise but not with the other noise of either (a) varying spectral characteristics or (b) brief duration noises with "spikes". Examples of such a system is found in U.S. Patent No. 4,025,721, to Graupe et al and U.S. Patent 4,185,168 to Graupe et al.

Other systems that do not offer selectivity, i.e., allow speech and warning signals to be heard, include the BOSE headset found in U.S. Patent No. 4,455,675 and other headsets with similar designs (e.g., CARME Patent No. 4,833,719).

The instant invention solves the problem now existant, that of <u>total</u> active attenuation of the noise by providing a solution of an active headset that can employ any of several selective algorithms such as those disclosed in U.S. Patent No. 5,091,953 to Tretter, hereby incorporated by reference herein. Alternatively, it can employ the algorithm disclosed in U.S. Patent No. 5,105,377 to Ziegler which is also incorporated herein by reference. In addition it can employ other algorithms such as

that disclosed in the application of Ziegler in U.S. Patent Application No. 07/421 759 which is hereby incorporated by reference herein.

Accordingly, it is an object of this invention to provide an active headset for canceling out undesirable noise and allowing speech in.

Another object of this invention is to provide an open back headset with active selective cancellation of unwanted noise.

These and other objects of this invention will become apparent when reference is had to the accompanying drawings in which

Fig. 1 is a diagrammatic view of an active/passive headset system embodying both passive and active techniques.

Fig. 2 is a diagrammatic view of the active only headset showing the control system.

Fig. 3 is a more detailed description of the system of Figure 2.

Fig. 4 is a diagrammatical view of the headset using the digital virtual earth controller.

In Fig. 1 there is shown an active/passive closed back headset system 10. It consists of a typical passive headset 11, loudspeakers 12 that drive the anti-noise and residual microphones 13 to sense any remaining noise near the ear and reference microphones 14 to send advanced information for feedforward control approaches and a system controller 20 which synthesizes the anti-noise signal.

The headset shown has closed backs 21, 22 for passive attenuation. Without the speakers, microphones and system controller, this headset would be a typical passive hearing protector.

Active noise cancellation is described in various patents to one Barry Chaplin, with U.S. Patent No. 4,654,871 being of particular interest in this case.

The system is designed to use various algorithms such as that of Ziegler in U.S. Patent 5,105,377, that of Tretter in U.S. Patent No. 5,091,953 or an adaptive feed forward approach. These algorithms use a reference signal as inputs. The digital virtual earth (DVE) algorithm develops a reference signal by subtracting an equalized

version of its own anti-noise signal from the residual signal. The adaptive feed forward uses the reference microphone as its input and is very effective on complicated noise environments that are broadband and random in character. The Tretter algorithm uses a sync signal as its reference signal. The Least Means Square (LMS) adapter 24 shown in Fig. 1 are Filtered - X versions which have inherent compensation for the effects of the feedback delays around the loop. Box "C" at 25 is the impulse response of the entire cancellation system.

Feedback compensator 26 and cancellation filter 27 complete the component portions of the controller.

DVE is highly effective to use in simple noise environments having only a few harmonics even where the noise varies tremendously, e.g., siren noise.

Speakers 12 of the headset are large enough to be capable of producing anti-noise at the same level as the noise to be canceled. They have little or no distortion and have a minimum of input-to-output delay as any delay in the feedback loop slows down the system adaptation rate.

Residual microphones 13 are typically small electret microphones mounted on the speaker frame near the ear. It must faithfully reproduce the sound that remains at the ear after cancellation so that the controller can make further adjustments to the anti-noise signal.

Reference microphones 14 are small electret microphones attached to the outside of the headset at a distance from the ear canal. This reference microphone is used to provide advanced information about the noise. The higher the frequency of the noise the more advanced information is needed to effectively cancel the noise.

The passive/active controller just described can be configured to selectively cancel only the damaging noise with minimal effects on speech and warning signals.

Fig. 2 shows the active only open backed headset system 50 with headset 51, speakers 52, residual microphones 53 and reference microphones 54. The controller 60 consists of adapters 61, 62, feedback compensation 63, impulse response 64 and cancellation filter 65.

Any of the aforementioned control approaches with the various algorithms can work on the system by attenuating all noise at frequencies below the speech band or to selectively cancel tonal noise within the speech band (300 to 3300 Hz). The active controller attenuates noise in the band of interest and allows speech and warning signals to pass through the open back headset design.. For noise below the speech band or slightly higher (below 1000 Hz), the adaptive feed forward described above would attenuate all sounds below the cutoff frequency chosen (dependent upon the noise) with minimal effects on the intelligibility of speech.

If the noise is comprised of tonal components below and well into the speech bands, selective noise control approaches would be used. These include the aforementioned digital virtual earth or a synchronous approach which is described in U.S. Patent No. 4,654,871 to Chaplin and which is hereby incorporated by reference herein. Both of these algorithms selectively cancel tonal noise. Digital virtual earth (DVE) selectively cancels the strongest tonal components in the frequency band of interest. The synchronous controller cancels the fundamental frequency based upon a synchronous input (e.g., tachometer from a propeller aircraft) and a limited number of it's harmonics in the frequency band of interest.

The system shown in Figure 4 configured as a digital virtual earth controller generates an output sample, y_k, given by

$$\underline{x}_k = \underline{r}_k - \underline{y}_{k-1} . \underline{C}_k$$

$$y_k = -\underline{A}_k \underline{x}_k$$

where y_k is the cancellation output value

$\underline{y}_{k-1}$ is a vector of previous cancellation output values

$\underline{C}_k$ is a vector of filter coefficients representing the impulse response of the entire cancellation system

$\underline{x}_k$ is a vector of estimates of the noise

$\underline{r}_k$ is a vector of most recent values of the residual signal

$\underline{A}_k$ is a vector of cancellation filter coefficients and

a.b is the dot product of the two vectors.

The output y_k is an anti-noise signal that passes through D/A, filters, and amplifier before driving the actuator in Figure 3. The input residual signal r_k is sensed from the residual sensor, amplified, filtered and sampled before input to the active controller.

DVE and the synchronous controller have been demonstrated on real systems to work effectively with tonal cancellation such as siren noise, aircraft propeller noise, and turbine noise. Adaptive feedforward has been demonstrated on simulated systems to work effectively doing broadband cancellation of noise between 50-3000 Hz as well as broadband noise below 1000 Hz.

CLAIMS

1. An active selective headset system which allows a user to selectively actively attenuate both high and low frequency noise, said system comprising

reference sensing means on said headset means adapted to sense speech, noise and warning signals,

residual sensing means on said headset means adapted to sense remaining sounds entering the ear canal,

speaker means on said headset means adapted to convey speech and warning signals to the user, and

controller means adapted to selectively attenuate both high and low frequency noise so as to pass only the warning signals and noise to the user.

2. A system as in claim 1 wherein said controller means is adapted to employ a digital virtual earth algorithm.

3. A system as in claim 1 wherein said controller means is adapted to employ a synchronous algorithm.

4. A system as in claim 1 wherein said headset means includes at least one open back muff.

5. A system as in claim 4 wherein said reference sensing means includes an electret microphone.

6. A system in as claim 4 where said residual sensing means includes an electret microphone.

7. A system as in claim 4 wherein said speaker means includes a speaker mounted internally on said open backed muff.

8. A system as in claim 1 wherein said controller means is adapted to employ an adaptive feedforward means.

9. A system as in claim 1 wherein said reference sensing means and said residual sensing means are the same.

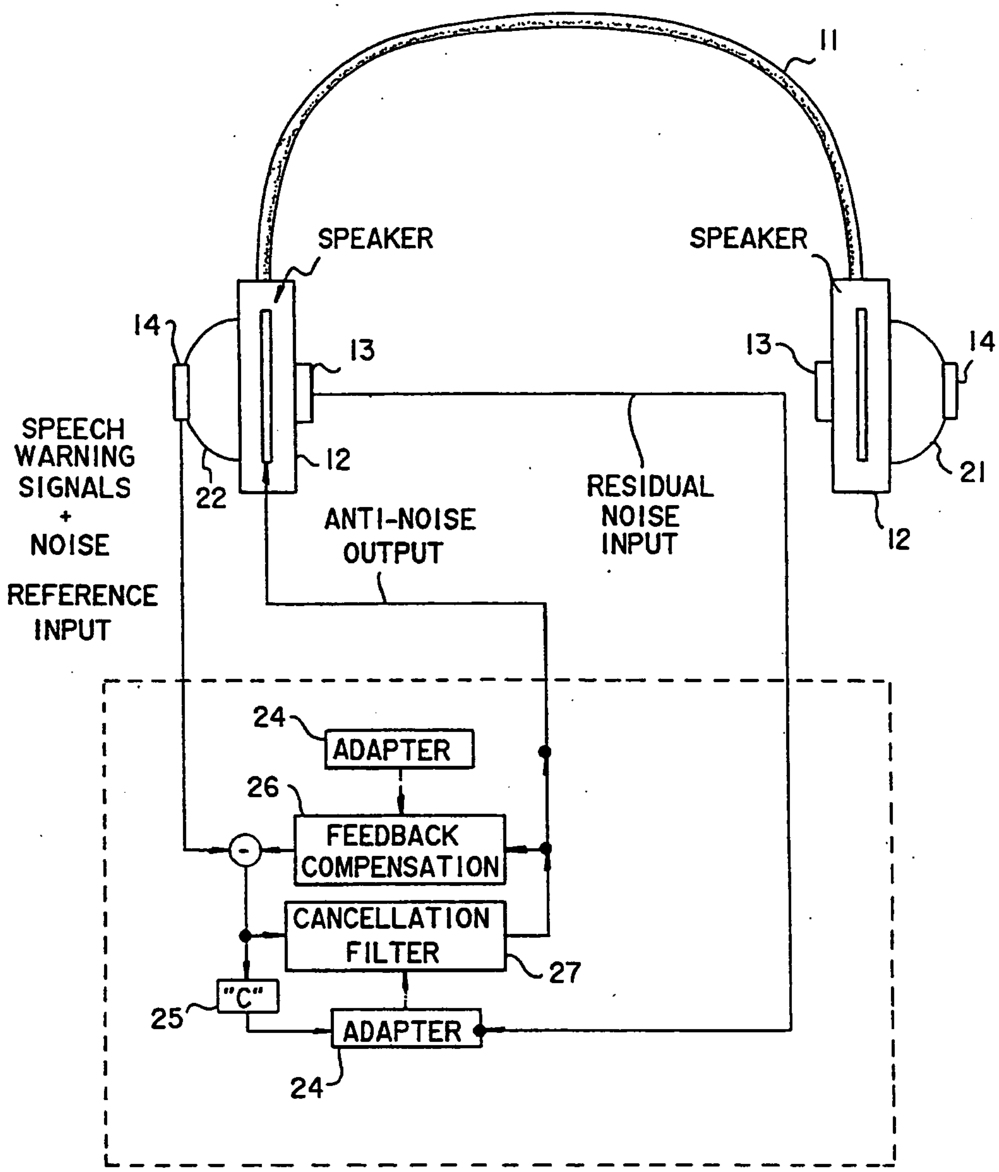
11
SPEAKER
SPEAKER
14
13
13
14
SPEECH
WARNING
SIGNALS
+
NOISE
REFERENCE
INPUT
22
12
RESIDUAL
NOISE
INPUT
21
12
ANTI-NOISE
OUTPUT
24
ADAPTER
26
FEEDBACK
COMPENSATION
-
CANCELLATION
FILTER
27
"C"
25
ADAPTER
24

FIG. 1

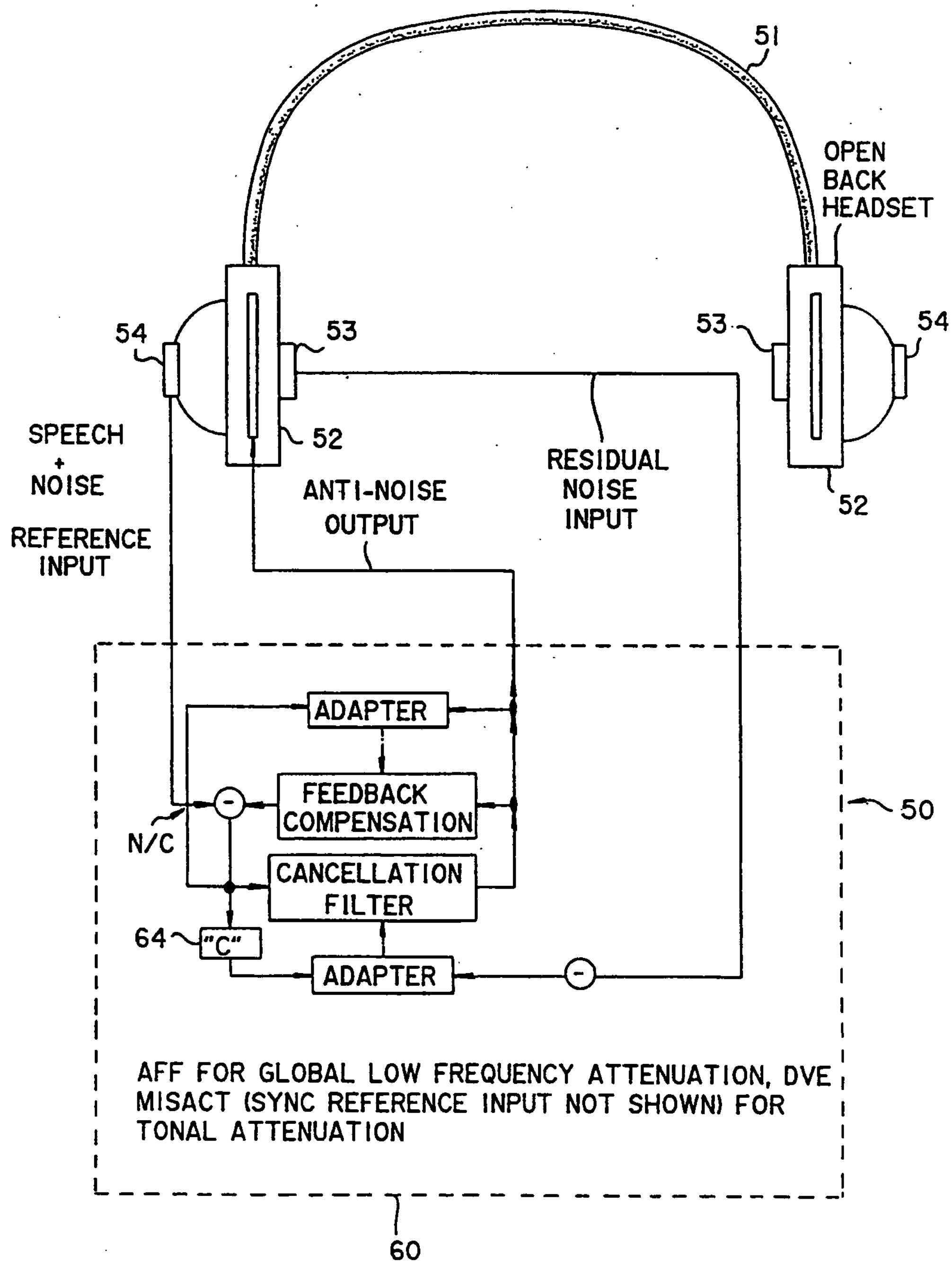
51
OPEN
BACK
HEADSET
54
53
53
54
SPEECH
+
NOISE
52
RESIDUAL
NOISE
INPUT
ANTI-NOISE
OUTPUT
52
REFERENCE
INPUT
ADAPTER
FEEDBACK
COMPENSATION
50
N/C
CANCELLATION
FILTER
64
"C"
ADAPTER
AFF FOR GLOBAL LOW FREQUENCY ATTENUATION, DVE
MISACT (SYNC REFERENCE INPUT NOT SHOWN) FOR
TONAL ATTENUATION
60

FIG.2

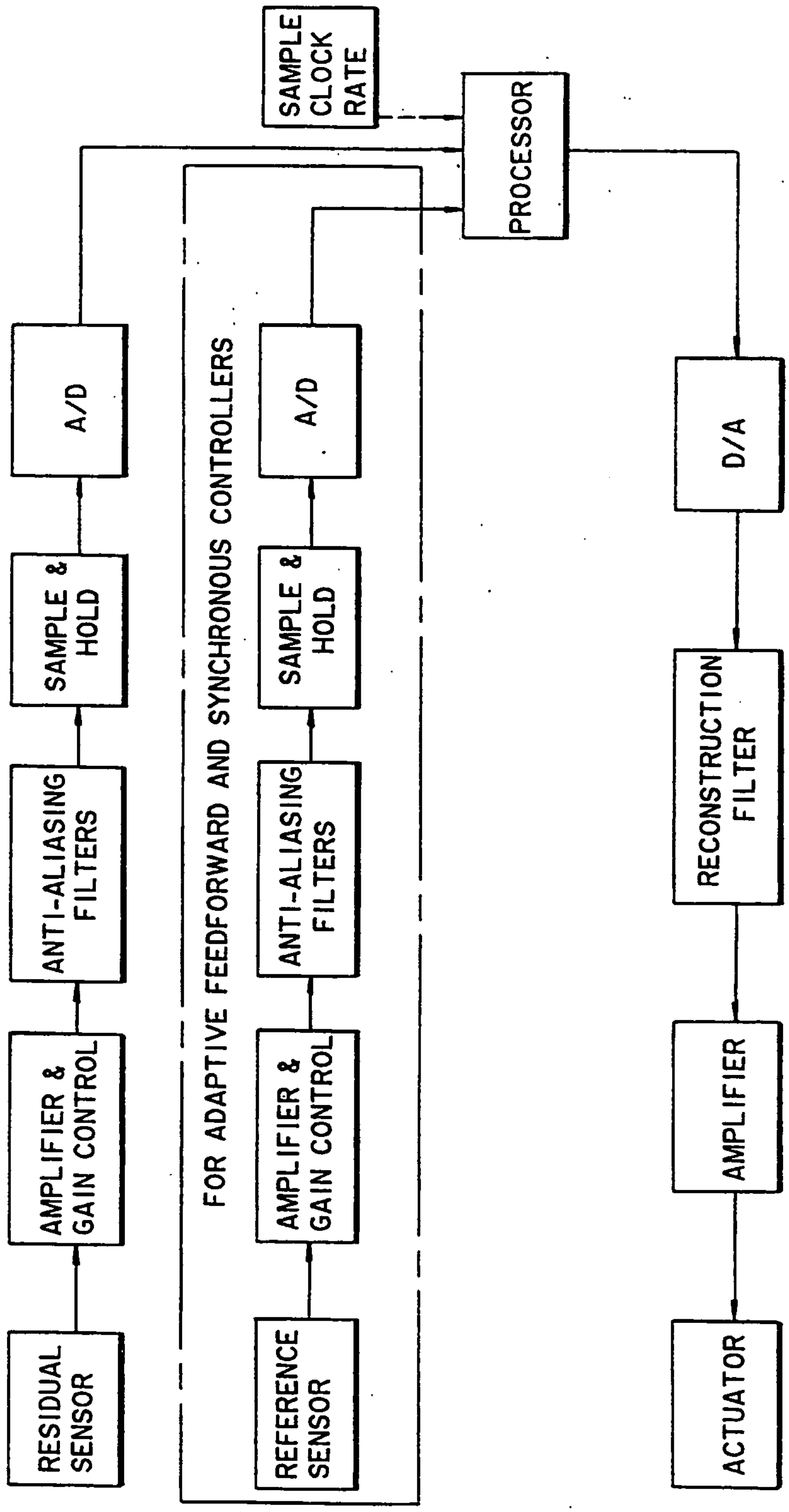
SAMPLE CLOCK RATE
PROCESSOR
RESIDUAL SENSOR
AMPLIFIER & GAIN CONTROL
ANTI-ALIASING FILTERS
SAMPLE & HOLD
A/D
FOR ADAPTIVE FEEDFORWARD AND SYNCHRONOUS CONTROLLERS
REFERENCE SENSOR
AMPLIFIER & GAIN CONTROL
ANTI-ALIASING FILTERS
SAMPLE & HOLD
A/D
D/A
RECONSTRUCTION FILTER
AMPLIFIER
ACTUATOR

FIG.3

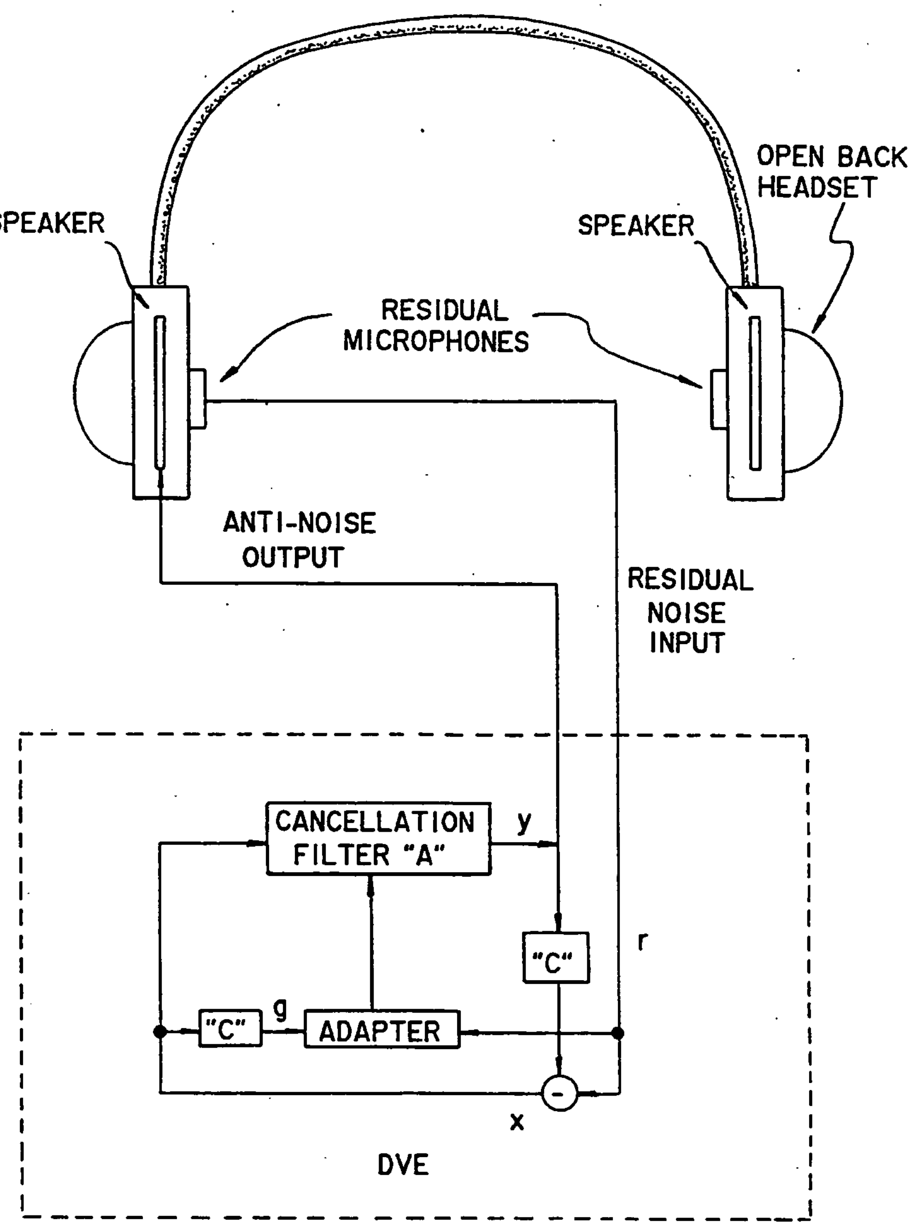
OPEN BACK HEADSET
SPEAKER
SPEAKER
RESIDUAL MICROPHONES
ANTI-NOISE OUTPUT
RESIDUAL NOISE INPUT
CANCELLATION FILTER "A"
y
"C"
r
g
"C"
ADAPTER
x
DVE

FIG.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/04569

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61F 11/02
US CL :381/72
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/72 381/71, 94

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,025,721 (GRAUPE ET AL.) 24 May 1977 See figure 3 and column 4, line 12 to column 5, line 57	1-8
Y	US, A, 4,654,871 (CHAPLIN ET AL.) 31 May 1987 See figure 1 and column 3, lines 23 to 65.	1-8
Y	US, A, 5,091,953 (TRETTER) 25 February 1992 See Abstract and Figure 1.	1-8
Y	US, A, 5,105,377 (ZIEGLER, JR.) 14 April 1992 See Figure 2 and column 3, line 37 to column 4, line 29.	1-8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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